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Oceanographic and Bathymetric Effects on Ocean Acoustics

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LONG-TERM GOALS

The focus of my recent research has been to develop an improved capability for understanding and predicting the signal and noise structure in the high-frequency (HF) band. The principal applications are: 1) acoustic communication networks, 2) HF environmental probing to sense the operating environment for navy systems, and 3) geoacoustic mapping via ambient noise. This work has developed some novel tools such as the VirTEX channel simulator that we would also like to extend to other applications, especially long range, low-frequency propagation. We also hope to establish more direct links to the physical oceanography and associated models (NCOM, SWAN, WaveWatch II).

OBJECTIVES

The central focus of this work is the extension of our Gaussian beam modeling tools to more completely model the propagation physics for broadband waveforms. Many of the problems (which are also opportunities to us) manifest themselves in the simulation of acoustic modem performance. The standard methods from low-frequency propagation work do not provide the scattered (reverberant) field. Neither do they model the distortion of the wave packets as they interact with a moving surface. Finally, they rarely treat the additional Doppler effects due to platform motion.

APPROACH

Last year we developed [1] a simulation tool called VirTEX (Virtual Timeseries Experiment), which has been distributed to various researchers, mainly for use in simulating acoustic modem performance. VirTEX is Matlab software that post-processes the echo pattern generated by the BELLHOP Gaussian beam tracing code. Doppler effects due to receiver motion are incorporated by simply sampling the pressure as the receiver moves through the sound field. Interpolation techniques are used so that the echo pattern can be tabulated on a coarse grid and re-sampled on a finer grid as the receiver moves through the field. A similar, but more involved interpolation process is used for surface-wave effects.

VirTEX is currently our most accurate approach to modeling the effects of surface-wave and platform motion on acoustic modem packets. However, to calculate *Modem Performance Maps* over slices of the ocean volume, we need to run thousands of packets through the virtual ocean. Despite the efficiencies derived from coarse-to-fine resampling in VirTEX, the run time is still prohibitive.

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14. ABSTRACT

The focus of my recent research has been to develop an improved capability for understanding and predicting the signal and noise structure in the high-frequency (HF) band. The principal applications are: 1) acoustic communication networks, 2) HF environmental probing to sense the operating environment for navy systems, and 3) geoacoustic mapping via ambient noise. This work has developed some novel tools such as the VirTEX channel simulator that we would also like to extend to other applications, especially long range, low-frequency propagation. We also hope to establish more direct links to the physical oceanography and associated models (NCOM, SWAN, WaveWatch II).

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Our modified approach is embedded in a new post-processor called VirTEX Lite. The algorithm is illustrated in Fig. 1. For a static platform, the received timeseries is simply the combination of direct path and echoes, each with its own amplitude and travel time. When we add the motion of a receiver platform (such as an AUV), we simply need to modify the echoes to include the Doppler associated with each path. The Doppler is the projection of the eigenray onto the velocity vector of the platform. The process is slightly more complicated for moving sources and surface waves.
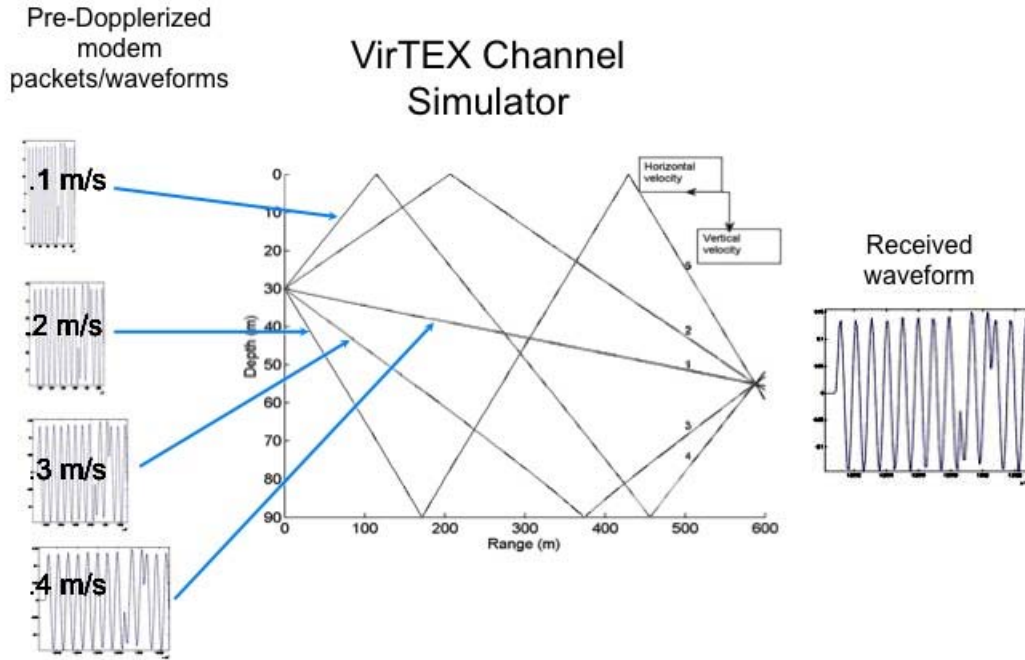

Figure 1: Overview of the VirTEX Lite algorithm. The waveforms are pre-Dopplerized, that is, pre-calculated using a time-stretching appropriate for the Doppler bins expected. The field at a given receiver location is a sum of echoes, each with it own amplitude, delay, and Doppler spread (based on the angle of the eigenray projected onto the velocity vector of the receiving platform).

WORK COMPLETED

VirTEX Lite has been fully tested and used for a number of different applications. It is also distributed on ONR's Ocean Acoustic Library (http://oalib.hlsresearch.com/), which is maintained by us to provide the latest open source R&D models. VirTEX Lite has also been integrated with target scattering models to produce waveforms received in a bistatic configuration. In this report, we concentrate on the acoustic modem application, which results will be presented in the next section.

Space does not permit a full discussion of all the efforts under this program so we have chosen to focus on VirTEX development. However, an important part of this work is to communicate the progress to

appropriate members of the S&T community. References [2-11] provide documentation of that effort. In addition, I gave a keynote presentation [8] on the history of computational ocean acoustics. A seminar series was also given in Korea including presentations at Seoul National University, Soongsil University, KORDI, ADD, and the Maritime University. The work has also been presented at various workshops [8-10].

RESULTS

As mentioned previously, one of the key motivators for VirTEX Lite was to be able to simulate the ocean channel effects on thousands of modem packets. That in turn allows us to study the performance of acoustic modems using either hardware or software implementations of the actual modems.

One of the very simple but powerful diagnostics that has emerged from this work is what we call a *Modem Performance Map*. An example is shown in Fig. 2. This map indicates the modem reliability as a function of its position in the ocean waveguide. The term 'reliability' is used very generally here. More precisely, the panels in sequence show 1) the input SNR to the modem, which is the source level minus the VirTEX transmission loss and minus the ambient noise level, 2) the equalizer SNR, which is measured after the modem attempts to recombine the various echoes, 3) the symbol SNR, which is measured after some matched-filter gain in processing the symbols, and 4) the packet completion. The latter is our most fundamental or 'bottom line' measure that indicates whether the modem was able to do everything (acquire and decode the packet) to produce an error-free packet.
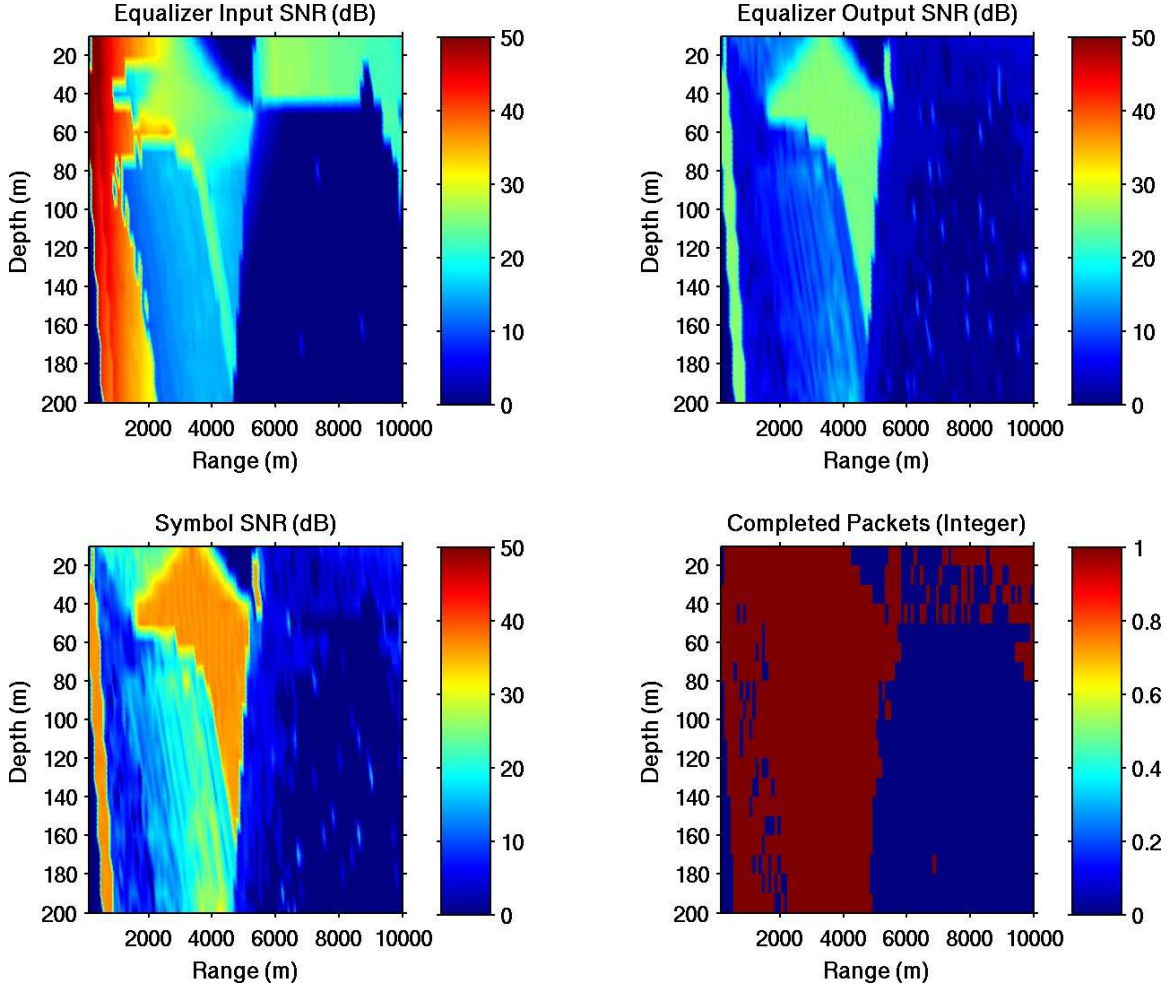
Figure 2: A Modem Performance Map over range and depth in the ocean channel. The panels in sequence show a) the equalizer input SNR, which is a direct measure of how loud the signal is at each hypothetical model location, b) the equalizer output SNR, measured after the modem has attempted to recombine the various echoes, c) the symbol SNR that incorporates some additional gain from matched filtering to the particular coded waveforms, and d) the Packet Completion. This last panel is the 'bottom line' that indicates whether a particular modem implementation (hardware or software) is able to decode the packet. Red is good here.

These simple maps are very revealing. For instance in this particular test case we discover that this PSK modem, using DSSS techniques is having trouble in the region where bottom bounce energy is strong. A naïve transmission loss interpretation will inform the user that this zone is an ideal location for the modem, since it receives the strength of packets that are both directly received on the Reliable Acoustic Path, as well as a strong bottom reflection. However, the Modem Performance Map shows that the modem is in fact confounded by the echoes and unable to decode. There is insufficient space for more detail; however, we note that this particular modem has a mode that exploits spatial diversity from a vertical receive array. With the array it is able to then suppress the bottom bounce path and get a clear signal from the direct path.

IMPACT/APPLICATIONS

The algorithms and software discussed here are clearly useful in understanding both underwater acoustic modems and active SONAR systems.

RELATED PROJECTS

We are involved in many projects, which are providing a rapid transition for the basic research being conducted here. The VirTEX (Virtual Timeseries Experiment) software has been made available to many investigators in ONR's Acoustic Communications MURI.

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